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# FORMCAST[TM] – High Pressure Forming Of Complex Geometries

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# FORMCAST™ – High Pressure Forming Of Complex Geometries

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## ABSTRACT

A near-net forming process, FORMCAST™, has been developed with the capability of forming components from ductile metals into complex three dimensional shapes. Excellent as-formed mechanical properties are achieved as the material is under constant, high pressure during the forming process generating significant levels of work hardening. FORMCAST™ shares characteristics with other conventional processes (i.e., forming, casting, and extrusion), yet eliminates porosity, the need for draft angles, non-uniform material properties, excessive scrap, and shrinkage concerns.

This paper will supply information to allow the comparison of FORMCAST™ to other processes. Items discussed will include the mechanics of the forming process, materials and that can be formed, as-formed material properties, characteristics, dimensional capabilities, and the process economics.

## MECHANICS OF THE FORMING PROCESS

The tooling associated with the process consists of a split or solid die with one or more punches. As the tooling closes the material being formed flows to conform to the final desired part configuration. The tooling is normally designed to form the near-net shaped part when all die and punch components are in contact. FORMCAST™ can utilize die cavity pressures exceeding 1000 MPa. A picture of a billet and formed part is shown in Figure 1.

During the forming process the billet may be exposed to preheat or formed at room temperature. The use of preheat will depend on the complexity of the part and the material being formed.

Lubricants used include powders, water-based, oil-based, and conversion coatings. The type of lubricant used will depend on the extent of surface expansion that occurs during forming, the material being formed, the forming temperature, and concerns associated with contaminants in certain lubricants depending on the intended use of the product.

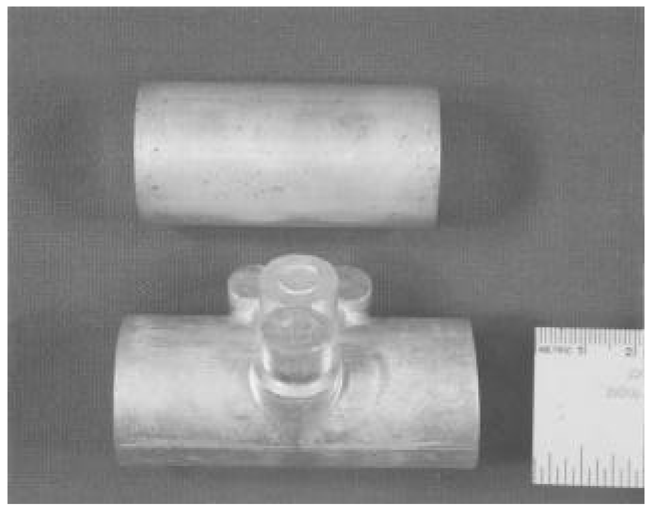

Figure 1. Brake Wheel Cylinder, Billet and Part

## MATERIALS AND SHAPES THAT CAN BE FORMED

Materials with good ductility and low to moderate yield strength can be formed. Materials that have been formed include 2XXX, 3XXX, 6XXX, and 7XXX series aluminum, low alloy steels, and certain copper alloys. Magnesium, brass, lead, and its alloys can also be formed.

FORMCAST™ can generate a wide range of shapes. Shapes that can be formed include cup-shaped parts (with a through or blind hole), cup-shaped parts with projections (hollow or solid), and cup-shaped parts with external recesses. Shapes that cannot be formed include double-ended parts, highly unsymmetrical parts, and parts with complex cores.

Table 1. Properties Of Various Alloys
"As-Formed" Data Is From FORMCAST™ Parts. Other Data From ASM Metals Handbook, 1992 Edition

| Alloy | Temper | Tensile Strength MPa | Yield Strength MPa | Hardness BHN | Percent Elongation |
|---|---|---|---|---|---|
| 2024 | T-0 | 186 | 76 | 47 | 20 |

Table 1. Properties Of Various Alloys
"As-Formed" Data Is From FORMCAST$^{TM}$ Parts. Other Data From ASM Metals Handbook, 1992 Edition

| Alloy | Temper | Tensile Strength MPa | Yield Strength MPa | Hardness BHN | Percent Elongation |
|---|---|---|---|---|---|
| | As-Formed | 240 | 160 | 69 | 9 |
| | T-48 | 469 | 324 | 120 | 19 |
| 3003 | T-0 | 110 | 41 | 28 | 30 |
| | As-Formed | 255 | 90 | 57 | 6 |
| | H-18 | 200 | 186 | 55 | 4 |
| 6061 | T-0 | 124 | 55 | 30 | 25 |
| | As-Formed | 230 | 170 | 70 | 9 |
| | T-6 | 310 | 276 | 95 | 12 |
| 6063 | T-0 | 90 | 48 | 25 | N/A |
| | As-Formed | 165 | 145 | 63 | 4 |
| | T-6 | 241 | 214 | 73 | 12 |
| 7075 | T-0 | 262 | 103 | 60 | 16 |
| | As-Formed | 360 | 205 | 83 | 11 |
| | T-6 | 572 | 503 | 150 | 11 |

Design reviews are common when considering the use of FORMCAST$^{TM}$ to manufacture parts. Guidelines that should be considered are as follows. No draft is required on the part. Wall and projection thicknesses may be as low as 0.5 mm, however thin projections that are connected to thicker sections, which are being formed perpendicular to the primary axis of the part can form flow defects. Parts should provide a constant cross section on projections. The cross section may decrease as the section moves away from the body of the part. Maximum part dimensions are limited to the capacity of the available press. Current products being formed range in mass from 0.01 Kg to 0.60 Kg.

When the shape of the part being formed lends itself to very high forming pressures a more detailed analysis is performed in the advanced planning phase. EDS Unigraphics is used to generate three dimensional models, which are analyzed using finite element analysis (FEA). FEA's are developed using MSC Patran/Nastran. This type of analysis is invaluable in assuring increased product and tooling reliability.

## MATERIAL CHARACTERISTICS AND PROPERTIES

During the forming the metal is maintained under high pressure at all times. This assures continuous material flow eliminating formation of voids, porosity, and most surface irregularities. This constant high pressure forming generates uniform material properties.

Table 1 lists a series of materials and the associated properties that have been FORMCAST$^{TM}$. As-formed strength of heat-treatable aluminum alloys approaches a T-4 state, and often meets design requirements.

The integrity of the parts formed exceed that of a cast component of the same design. This is due to an oriented grain structure that is a consequence of material flow rather than a solidification process. Generally, the casting process creates an isotropic grain structure with significant mechanical property variations from the core of the part to the surface. This permits less material to be used to meet performance standards due to an increased strength to weight ratio.

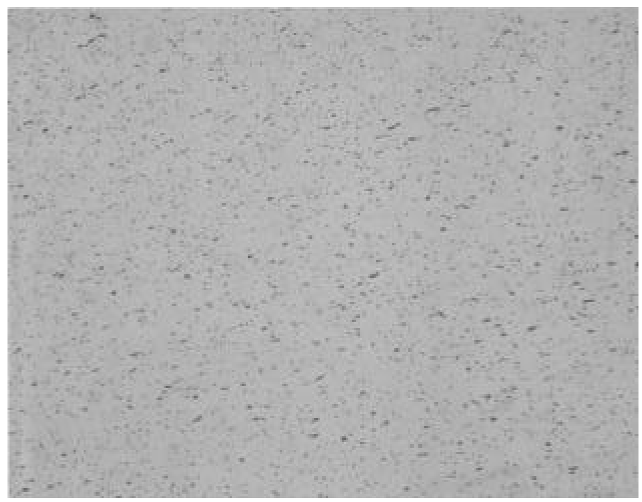

Figure 2. FORMCAST$^{TM}$ 6061 Material, 200X

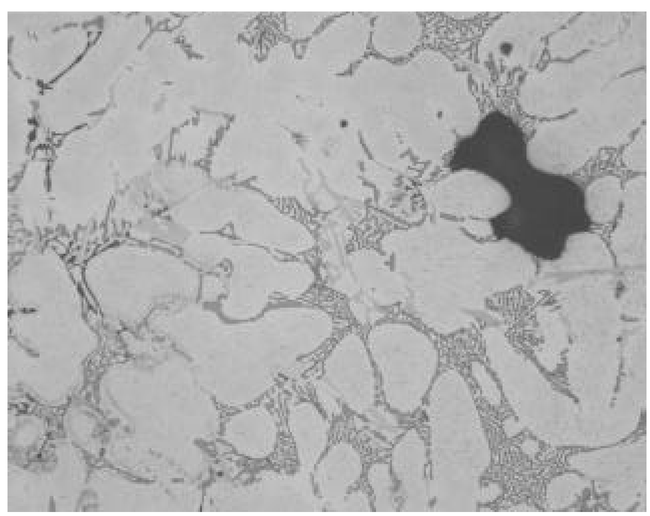

Figure 3. A-356, Cast Material, 200X

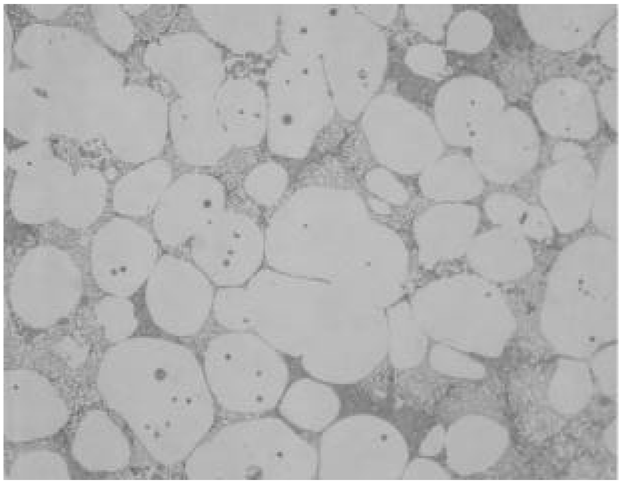

Figure 4.   A-357, Semi-Solid Material, 200X

Figures 2, 3, and 4 illustrate three heat-treatable aluminum alloys. Figure 1 is 6061 FORMCAST$^{TM}$ material. Note the very uniform matrix. Figure 2 shows an A-356 cast material. This is a typical cast microstructure, susceptible to porosity and varying in composition from core to part surface. Figure 3 is A-357, semisolid-metal alloy. The microstructure is similar to A-356, yet consists of a more sheroidal composition.

Testing has demonstrated that the process can utilize mechanical or hydraulic forming machines and produce a quality product. This testing implies that forming under high pressure exhibits no strain rate sensitivity.

## DIMENSIONAL CAPABILITIES

Products produced with the FORMCAST$^{TM}$ process exhibit very good dimensional repeatability. The parts are formed with a single set of precise tools. This eliminates concerns associated with dimensional variation as a result of multiple mold cavities. It should be noted that processes such as multiple-hit forging operations can produce similar dimension variations. The repeatability of certain dimensions is limited to the capability of the tooling manufacturer to maintain datums. Additionally, because the parts are cold (or warm) formed, there is no dimension variation created as a result of phase changes during the cooling process, inherent to the casting process.

Figures 5 through 8 represent products that have been formed with the FORMCAST$^{TM}$ process. Figure 5 shows a part as it would look when ejected from the die. Figures 6, 7, and 8 represent products with finishing operations such as roll threading, piercing, and as shown in Figure 8, the brazing in of fittings. Table 2, above Figures 5 to 8, is a matrix of capabilities of selected dimensions taken from similar formed parts.

## PROCESS ECONOMICS

The capability to produce a near-net shaped component offers several advantages into itself. Due to the extreme levels of cold working that occur, the strength of the part often meets design requirements as-formed. This can eliminate the need for subsequent thermal treatment.

Several FORMCAST$^{TM}$ parts have originated from the need to simplify the design. An example of this is shown in Figure 2. This part is formed in one piece. The alternative means of producing the part requires the fitting to be turned on a screw machine, the tube cut to length, and then the two pieces are brazed together. This alternative technique is not only more costly, but the product reliability is diminished due to the potential of the brazed joint failing to hold a seal.

When compared with alternative processes, additional opportunities become apparent. FORMCAST$^{TM}$, as compared to casting, requires no draft angles, does not require molten material, needs no risers, and no waiting for the part to solidify is necessary. This significantly reduces scrap, energy costs, machining, and processing time.

Multiple-hit impact forge operations often require the use of controlled flash in order to encourage material flow to accommodate a total cavity fill. FORMCAST$^{TM}$ parts, formed in a single operation, require no controlled flash. This reduces scrap and subsequent trim operations.

## SUMMARY

FORMCAST$^{TM}$ is a near-net forming process used to produce components of high structural integrity using low to moderate strength materials having good ductility. The process produces parts possessing a high degree of dimensional accuracy.

Manufacturing cost of the FORMCAST$^{TM}$ process are favorable when compared to competitive processes. Cost advantages include reductions in, but are not limited to, assembly costs, work in progress, machining time, and scrap due to lack of flash, risers, and drafts. Additionally, FORMCAST$^{TM}$ components are lighter weight due to superior material properties and offer an improved surface finish.

Table 2.      Typical FORMCAST$^{TM}$ Process Capabilities

| | Suspension Arm | Evaporator Fitting | Evaporator Manifold | Condenser Manifold |
|---|---|---|---|---|
| Primary Inner Diameter | 2.9 | 2.6 | N/A | 1.9 |
| True Position - Riser(s) | 3.2 | N/A | N/A | 4.6 |
| Overall Length | 2.3 | N/A | N/A | N/A |
| Fitting Inner Diameter | N/A | 3.4 | 1.8 | N/A |
| Primary Outer Diameter | N/A | 3.1 | N/A | N/A |

Figure 5. Suspension Arm and Billet

Figure 6. Evaporator Inlet Fitting and Billet

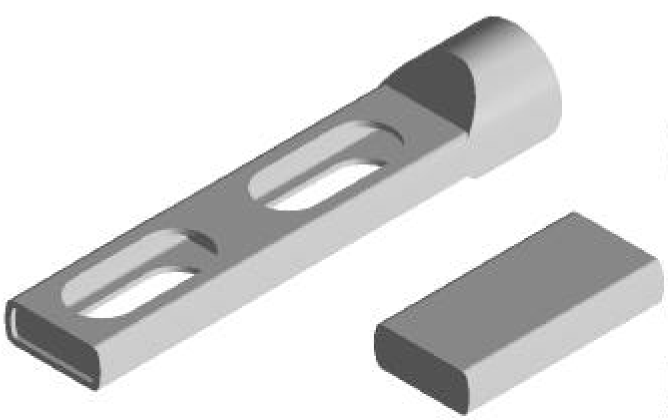

Figure 7. Evaporator Manifold and Billet

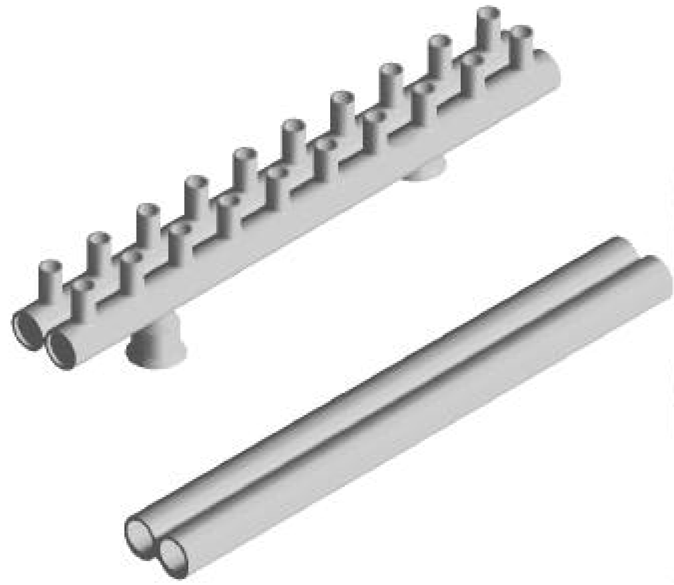

Figure 8. Condenser Manifold and Billet